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Utilization of submandibular ultrasound to measure oral cavity changes with interventions in routine airway management

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ABSTRACT

Ultrasound is a quick, noninvasive, inexpensive tool that can provide an accurate airway assessment. Tongue thickness, oral cavity height, and their relationship were measured using submandibular ultrasonography with and without oral airway interventions during intubation in 26 patients. The mean tongue thickness to oral cavity height ratio was 0.83 ± 0.03. The percent change of tongue thickness to oral cavity height decreased significantly by 36.47% with an oral airway and by 43.49% with laryngoscope interventions ($P < 0.01$). This study demonstrates how ultrasound-measured oral cavity ratios change with the placement of airway equipment, and application of these findings may advance our understanding of advanced airway management among diverse patient populations.

KEYWORDS Airway management; oral cavity; point-of-care ultrasound; submandibular sonography

Airway management is a crucial aspect of anesthesiology, emergency, and critical care practice, and unanticipated difficult airways can present as potentially life-threatening clinical scenarios.[1] Although bedside screening tools provide a valuable assessment, they have poor to moderate sensitivities for predicting difficult airways.[2,3] Point-of-care ultrasound (POCUS) is increasingly utilized as a diagnostic tool in a myriad of clinical settings because it is safe, cost effective, and reliable. POCUS measurements may even closely correlate with more sophisticated imaging such as magnetic resonance imaging, and emerging evidence supports ultrasound as a useful tool for preoperative airway assessment in oral cavity measurements.[4–7] This initial observational study explored the ability of POCUS to capture the relationship of tongue thickness (TT) to oral cavity height (OCH) in the normal airway and to investigate how common airway maneuvers such as placing an oral airway or laryngoscope alter this relationship.

METHODS

All patients in this study were scheduled for elective surgery at an academic urban hospital. Subjects who were scheduled for elective surgery requiring general anesthesia with oral endotracheal intubation were recruited and consented preoperatively. The only exclusion criterion was the inability to self-consent. The university institutional review board approved this study (IRB # NCR203147). All data were captured and stored in REDCap (Vanderbilt University, Nashville, TN).

Ultrasound scanning was performed by two attending anesthesiologists with previous experience and training in airway POCUS. Airway sonography was performed using a SonoSite X-porte Ultrasound system (FujiFilm, Philips Healthcare, Bothell, WA) equipped with a 3 to 8 MHz curvilinear transducer. For the preoperative measurements of TT and OCH, the patient was placed in a supine position with the head in a relaxed position. The ultrasound was placed in a sagittal orientation. TT was measured between the geniohyoid muscle and the dorsum of the tongue, and OCH was measured as the

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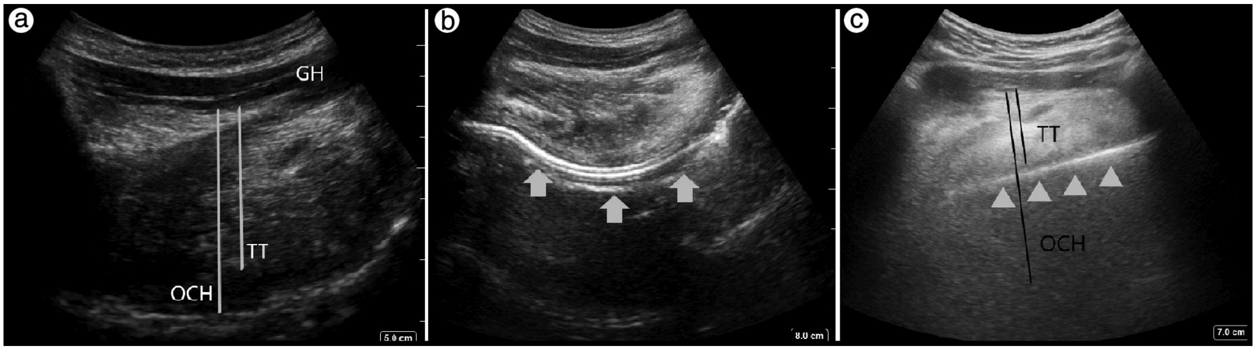

Figure 1. Submandibular ultrasonography of the oral cavity. **(a)** Tongue thickness (TT) and oral cavity height (OCH) measurements in the awake patient. **(b)** Scan from an anesthetized patient with the oropharyngeal airway (arrow) in place. The concave nature of this device is clearly evident. **(c)** Sagittal scan from an anesthetized patient with a Miller laryngoscope in place (arrowhead). GH indicates geniohyoid muscle.

geniohyoid muscle to the hard palate. For the postinduction measurements, the patient was placed in a similar position and imaging was performed in a similar manner with the airway device placed by the anesthesiologist *(Figure 1)*.

Measurements were compared between outside observers to ensure interrater reliability. Any measurements with >10% discrepancy ($n = 1$) were excluded from analysis. Ultrasound measurements of TT and OCH and the TT to OCH ratio were obtained and compared both before and after placement of an oral airway and during direct laryngoscope, when the laryngoscope blade was initially placed in the mouth, prior to the intubating provider putting any upward force on the laryngoscope. For the purpose of this study, Macintosh and Miller laryngoscope blades (Flexicare Medical Limited, Irvine, CA) were used at the discretion of the anesthesiologist. Oral airways were either 7, 8, or 9 cm in length and chosen for ideal fit for the patient.

Mean and standard deviation were measured for all data sets. The correlation between two ordinal variables was tested by the Pearson correlation. The mean values for two oral cavity measurements were compared using the paired *t* test. Statistical significance was set at $P < 0.05$. Data analysis was performed using SPSS, version 27 (IBM Corp., Armonk, NY).

RESULTS

Twenty-six patients were recruited and underwent perioperative airway POCUS exam, including 15 (58%) women and 11 (42%) men. The average body mass index of our patient population was 32.3 ± 7.9 kg/m^2 (range, 19.5–50.9 kg/m^2), and the average neck circumference was 38.6 ± 3.7 cm (range, 31.4–42.4 cm). Two patients had a grade 3 Cormack-Lehane score, and no patients required multiple intubation attempts. The mean TT to OCH ratio was 0.83 ± 0.03 prior to placing an oral airway or direct laryngoscope, 0.53 ± 0.05 with an oral airway, and 0.47 ± 0.06 with a direct laryngoscope *(Table 1)*.

Table 1. Patient demographics and measurements (n = 26)

Variable	Mean	SD
Male: n (%)	11	42%
Female: n (%)	15	58%
Age (years)	56.28	12.44
Body mass index (kg/m^2)	32.34	7.9
Neck circumference (cm)	38.58	3.7
Baseline		
Tongue thickness	3.04	0.48
Oral cavity height	3.65	0.54
Ratio	0.83	0.03
Oral airway		
Tongue thickness	1.99	0.26
Oral cavity height	3.76	0.32
Ratio	0.53	0.05
Direct laryngoscope		
Tongue thickness	1.96	0.25
Oral cavity height	4.18	0.29
Ratio	0.47	0.06

The percent change of the TT to OCH ratio, compared to measurements without intervention, decreased significantly by 36.47% with oral airway and by 43.49% with direct laryngoscope ($P < 0.01$). The TT to OCH ratio with direct laryngoscope was significantly decreased compared to the oral airway at 11.04% ($P < 0.01$; *Table 2*). There was no statistically significant difference in measurements between genders. No significant differences were observed between TT or TT to OCH ratio across body mass index or neck circumference. However, when observing OCH and TT to OCH ratio with an oral airway placed, age was statistically significant ($P < 0.05$; *Table 3*).

DISCUSSION

Because upper airway anatomy is indicative of the pathogenesis of a difficult airway and ultrasound has been shown

Table 2. Paired comparison of oral cavity measurements (n = 26)

Pair	Variables	SD	% Mean reduction	95% CI of differences Lower	Upper	*P* value
1	TT and TT with OA	0.40	34.59	0.89	1.21	<0.0005
2	TT and TT with DL	0.49	35.47	0.88	1.28	<0.0005
3	TT with OA and TT with DL	0.31	1.33	–0.1	0.15	0.667
4	OCH and OCH with OA	0.52	–2.97	–0.32	0.10	0.298
5	OCH and OCH with DL	0.63	–14.49	–0.79	–0.27	<0.0005
6	OCH with OA and OCH with DL	0.43	–11.19	–0.59	–0.25	<0.0005
7	Ratio and Ratio with OA	0.05	36.47	0.28	0.32	<0.0005
8	Ratio and Ratio with DL	0.05	43.49	0.34	0.38	<0.0005
9	Ratio with OA and Ratio with DL	0.06	11.04	0.03	0.08	<0.0005

CI indicates confidence interval; DL, direct laryngoscope; OA, oral airway; OCH, oral cavity height; ratio, tongue thickness to oral cavity height ratio; SD, standard deviation; TT, tongue thickness.

Table 3. Correlation of neck circumference and BMI with ultrasound measurements

	Variable	NC	BMI	Age	TT	OCH	Ratio	TT with OA	OCH with OA	Ratio with OA	TT with DL	OCH with DL	Ratio with DL
NC	Pearson correlation	1	0.387	0.204	0.319	0.326	0.042	0.156	0.197	0.057	0.327	–0.071	0.367
	P value		0.051	0.327	0.112	0.104	0.838	0.446	0.335	0.781	0.103	0.732	0.065
BMI	Pearson correlation	0.387	1	–0.34	0.215	0.261	–0.148	0.028	–0.289	0.305	–0.057	–0.238	0.079
	P value	0.051		0.096	0.292	0.198	0.471	0.891	0.152	0.129	0.783	0.242	0.701
Age	Pearson correlation	0.204	–0.34	1	0.065	0.001	0.3	–0.014	0.424	–0.418	0.181	–0.034	0.18
	P value	0.327	0.096		0.759	0.995	0.145	0.945	0.035	0.038	0.388	0.87	0.389

BMI indicates body mass index; CI, confidence interval; DL, direct laryngoscope; NC, neck circumference; OA, oral airway; OCH, oral cavity height; TT, tongue thickness.

to be a reliable imaging modality of the tongue, we explored the utility of ultrasound in accurately evaluating changes in the oral cavity. Our findings define a standard of ultrasonographic measurements in normal patients and the effect of airway equipment. Furthermore, our preliminary observations can be utilized to launch future investigation into pathological airway swelling and could have implications for the management of such patients.

Our primary outcome of a mean TT to OCH ratio of approximately 83% without the intervention of airway devices is consistent with existing literature.[8–10] To our knowledge, our study is the first to explore how these ratios change with an oral airway and direct laryngoscope. By placing an oral airway, the percent change decreased significantly by 36.47%. The purpose of an oral airway is to stabilize the dorsum of the tongue and prevent it from collapsing onto the palate and larynx, thereby allowing for easier ventilation. These results suggest that airway devices also depress the tongue, which increases unoccupied space in the oral cavity. With direct laryngoscopy, an additional 43.49% of vacant airway is added. This increase with laryngoscopy is likely a function of the upward force of the blade, which displaces the mandible and further opens the oral cavity. The fact that ultrasound can capture these changes and quantify them provides a standardized bedside imaging option when assessing upper airway anatomy and the role of routine airway management techniques in altering such anatomy.

The TT to OCH ratio has not been shown to predict difficult intubation in the normal patient.[7] However, the upper limits of measured TT to OCH ratio have not exceeded 0.9, leaving at least 10% of the oral cavity available for ventilation and airway management. In a pathological situation, the remaining 10% may be occupied by edema and/or malignant growth. Further studies are needed to determine whether at some point a greater TT to OCH ratio increases the difficulty of airway management in a patient with abnormal tongue pathology. A case report describing a patient presenting with mild angiotensin-converting enzyme–induced angioedema utilized POCUS to investigate the airway edema that was only clinically evident by the patient's swollen lips.[11] The tongue was not visibly enlarged so the investigators focused their ultrasonography on the more distal airway, concentrating on the periglottic structures. However, this is an illustration of how submandibular ultrasonography can be utilized to assess and track the severity and course of more significant oral edema, specifically in the tongue and oral cavity.

In previous reports investigating tongue size and difficulty of intubation, tongue volume was also measured.[10–13] As has been reported, the measurements of tongue volume rely on the assumption that the tongue is an actual uniform cylinder, which inherently overestimates these measurements because the tongue is not so uniform in shape.[14] Presumably, instrumentation of the airway, either via oral airway or direct laryngoscope, does not in actuality change the total volume of the tongue, but rather deforms the shape to a greater extent, making any calculated measurements of tongue volume further erroneous. Therefore, we did not attempt to measure tongue volumes with these airway devices in place.

One limitation of this study is the small sample size. Since our results were in accordance with previous measurements reported in the literature and this was a preliminary observational study of the effect of inserting instrumentation in the airway, we felt that our sample size was sufficient to accomplish this goal. Furthermore, the preoperative measurements were made prior to induction of general anesthesia. Given that common anesthetic drugs are known to relax the airway musculature and anatomy, there is the potential that the airway devices (oral airway and direct laryngoscope) had less effect on opening the airway, with a portion of the measured effect being due to the paralytic actions of induction agents. No information is known regarding the ultrasonographic changes in the oral cavity due to induction agents, so this could be a source of error in our measured changes with airway devices.

In conclusion, current standards for screening and prediction of a difficult airway are relatively subjective, with poor sensitivity and specificity. We show that ultrasound is an effective imaging modality that can locate anatomical structures and their changes with airway management devices. Therefore, by gaining knowledge of how airway devices such as an oral airway or rigid laryngoscope affect the normal tongue with respect to OCH, future investigations may explore how best to use POCUS to manage the airway of a patient with tongue pathology.

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